Preliminary Study on Passive System Experimental with Water Initial Temperature Variation in Transient Condition using NC-Queen Apparatus

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1. Background

The first accident of nuclear power plant (NPP) related to failure of thermal management was occurred at Three Mile Island Unit 2 (TMI-2) in the pressurized water reactor (PWR) in 1979 and the second accident in the boiling water reactor (BWR) at Fukushima Daiichi on March 11, 2011. The research om the boiling heat transfer in narrow channel have been done by authors [1-2] focusing on phenomena during debris cooling process in transient condition. The results of research related to rewetting phenomenon, CHF and CCFL. Then, concerning Fukushima NPP severe accident condition caused by the absent of cooling process (active system) in primary system due to the diesel generator damage by tsunami, it was made core-meltdown in which reactor pressure vessel (RPV) was damaged and leakage was occurred. The conclusion of this severe accident was showed that the thermal management have failed and decay heat become a trigger for core meltdown as a result of no operation of active systems was done by the pump. That situation should not occur if the backup system, such as passive system (no pump needed) take over cooling process in primary loop. It can be said that the part of passive system in the event such Fukushima Daiichi NPP accident should be implemented to prevent the damage of RPV. So, the understanding of passive system phenomenon become an important topics in research to prevent severe accident in light water reactor (LWR) due to transient cooling process. Then, in passive system research, many researchers[3-13] have been investigating the phenomenon of natural circulation for application through passive residual heat removals system (PRHRS).

In this synopsis, base on the research history from all the above research was conducted during steady state condition, thus the study related to decay heat as transient cooling conditions needs to be done. An experimental study as a preliminary research has begun conducted with experiment purposes is to investigate the effect of initial temperature in heater to mass flow rate inside rectangular loop during transient cooling. A sequel of experiment carried out to investigate the influences of the difference on initial temperature to mass flow rate inside loop. An experimental apparatus, called NC-Queen appratus was constructed and it used as the object of study.

2. Description of The Research Work

2.1. Experimental Setup

The experimental setup for NC-Queen apparatus (as shown in Fig.1) consists of rectangular loop(1) as main object, computer(2) as data recorder, NI-Daq(3) as data acquisition system, expansion tank(4) as pressure stability, refrigrator(5) as cooler, heating-Queen(6) as heat source and regulator voltage(7) as power unit. Figure 2 shows the rectangular loop is the main equipment of passive system consists of cooler with refrigerator of power 1/5 HP (149 watt) and cooling capability until -10°C, heater with maximum power 3000 watt and heating capability until 300°C.

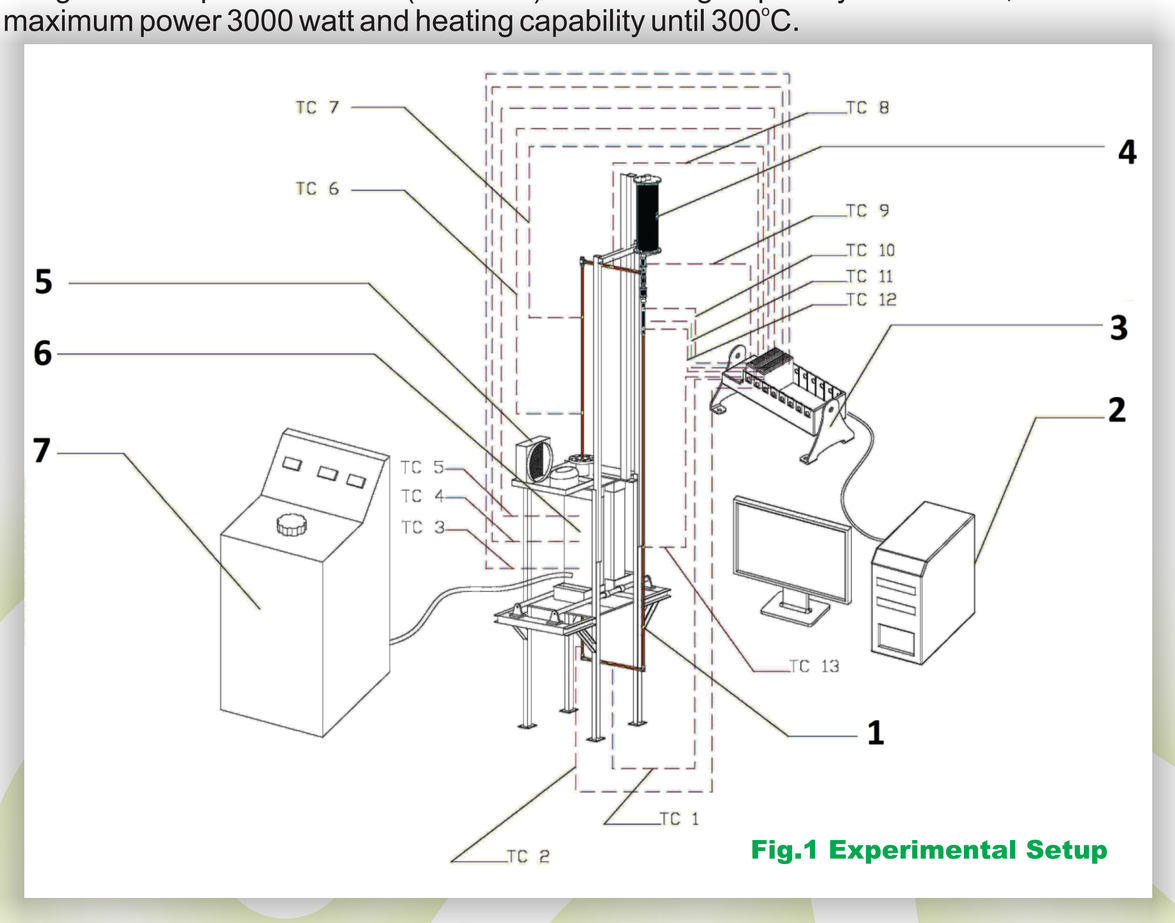

Fig.1 Experimental Setup

2.2. Results and Discussion

Figures 2(a), 2(b) and 2(c) presented the curves of temperature profile based on time during transien cooling for variation temperatures 70°C, 80°C and 90°C. Curve explained three line of water temperature in heater area, water temperature in cooler area and the average temperature. From all figures shows that, in heater area and cooler area the temperatures was decreased. Because, there is no additional heat into the heater area, then cooler was worked to remove heat in rapidly. During 5000 seconds, temperature in heater area was decreased in 36.16°C, 46.1°C and 50.86°C in respectively for initial temperatur 70°C, 80°C and 90°C.

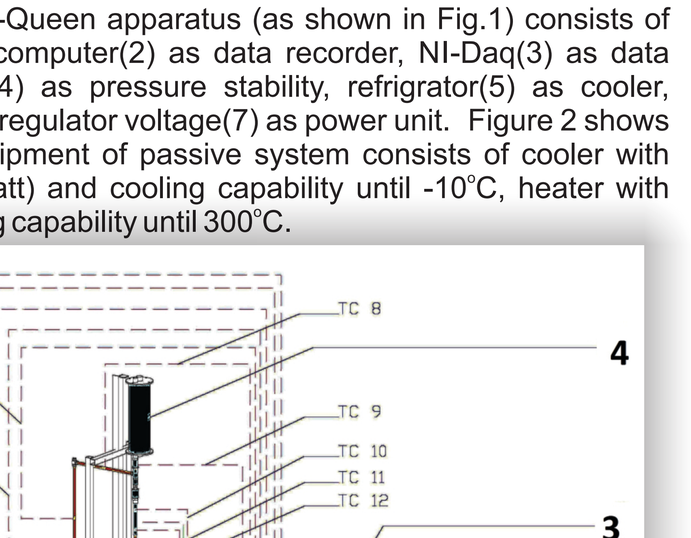

Fig.2(a) Temperature measurement in heater and cooler at 70°C

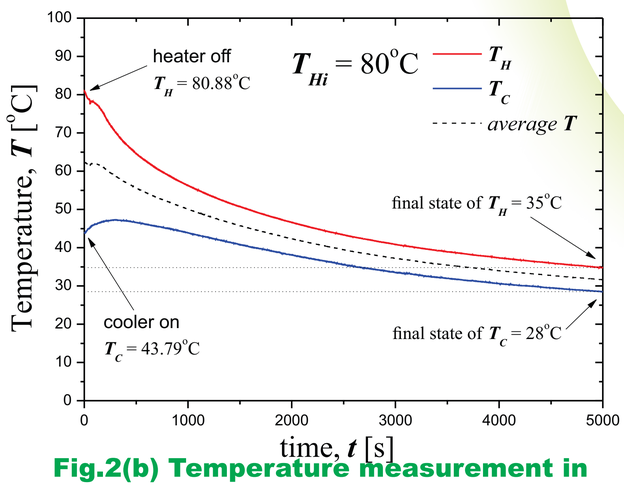

Fig.2(b) Temperature measurement in heater and cooler at 80°C

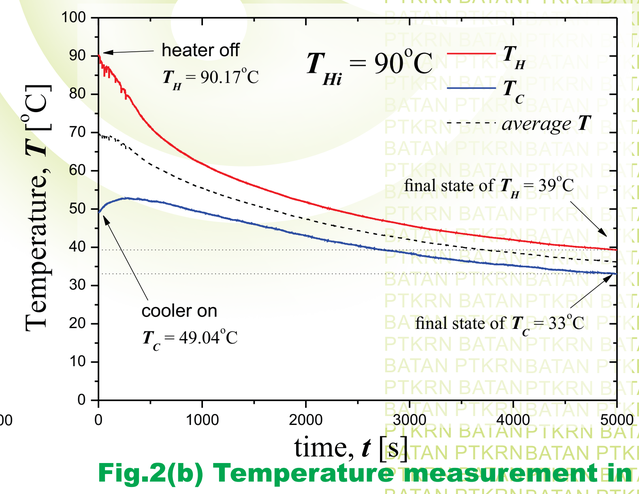

Fig.2(b) Temperature measurement in heater and cooler at 90°C

The temperature measurement in heater and cooler area with three variation of water initial temperature in heater area (T_{Hi}) taken into acount using this correlation:

$$\dot{m} = A\frac{\left(-64\mu L + \sqrt{(64\mu L)^2 + 8gHK\bar{\rho}_w D^4(\rho_c - \rho_h)}\right)}{2KD^2}$$

Representating curve was made to show the relationship between water mass flow rate to time cooling and the relationship between maximum water mass flow rate to T_{Hi} as shown in Figure 3 and Figure 4.

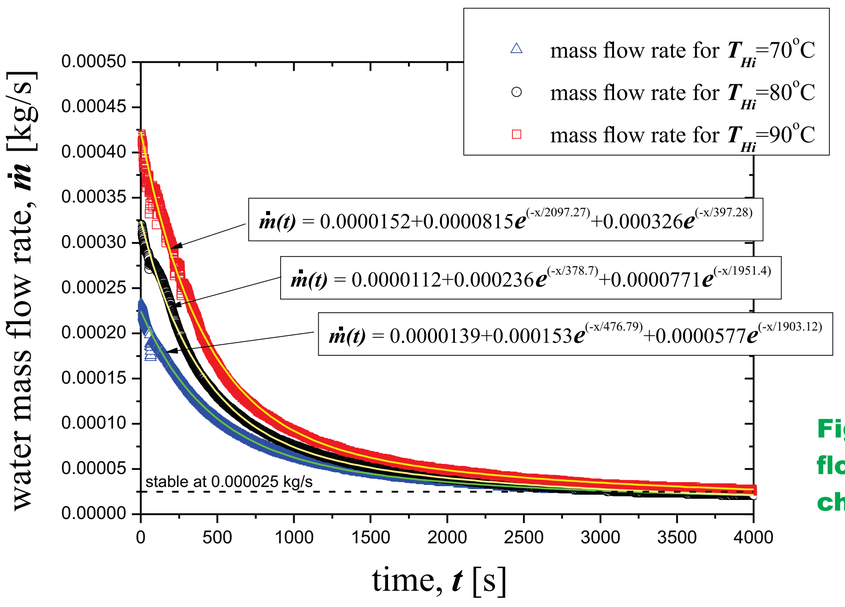

Fig.3 Water mass flow rate characteristics

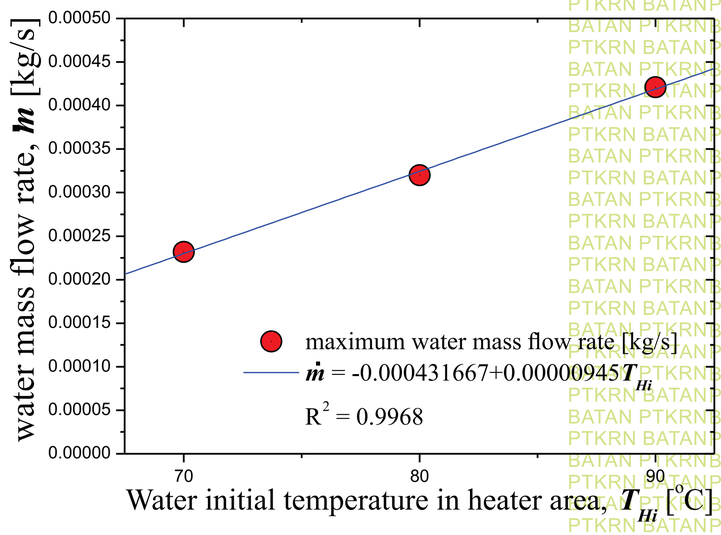

Fig.4 Maximum water mass flow rate base on T_{Hi}

The characteritic of water mass flow rate in Figure 3 shows that the exponential curve for three variation of initial temperature in heater area is almost the same. The amount of heat remaining in heater area was decreased due to cooling process in cooler. The results of mass flow rate is not the same if the heater was maintained in constant (heat additional). Figure 3 shows that the correlation of maximum water mass flow rate as a finction of water initial temperature in heater area. The correlation is a linier correlation and need more data to ensure the validity. The experimental results from this preliminary research has shown the characteristic of water mass flow rate in transient condition based on initial temperature variation in heater area. Further research will involve more parameters and scenario conditions (transient and steady state).

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Poster ID Number:
IEM on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant,
IAEA Headquarters, Vienna, Austria, 16–20 February 2015